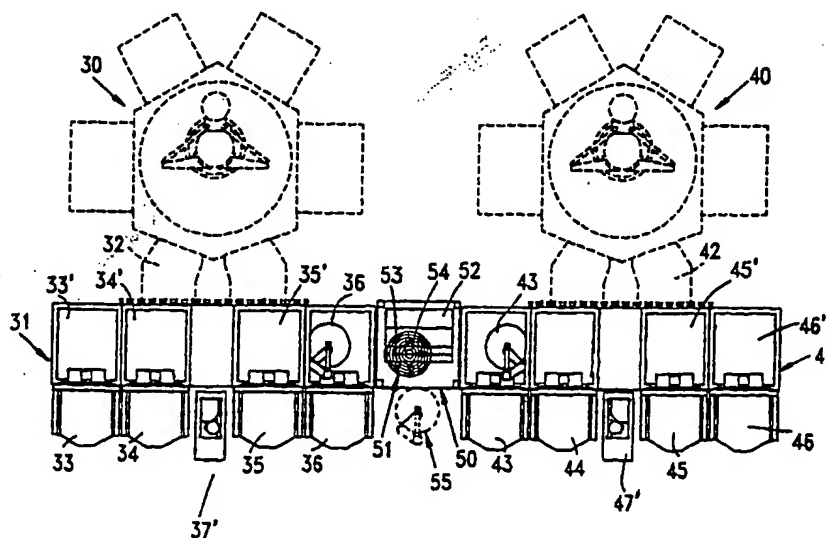




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(54) Title: A WAFER BUFFER STATION AND A METHOD FOR A PER-WAFER TRANSFER BETWEEN WORK STATIONS



## (57) Abstract

A buffer station is disclosed, for a "per wafer" transfer of wafers between work stations. The wafers are retrieved from the pod by a track robot at a first work station and are processed. When the processing at the first work station is completed, the track robot takes the wafer and, rather than returning it to the pod, places the wafer in the buffer station. When the second work station is ready to accept the wafer, its track robot retrieves the wafer from the buffer station and inserts it into the second work station for processing. When processing is completed at the second work station, the track robot inserts the wafer into a pod located at the second work station.

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**A WAFER BUFFER STATION AND A METHOD FOR A  
PER-WAFER TRANSFER BETWEEN WORK STATIONS**

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**Field of the Invention**

This invention relates to a method and an apparatus for improving throughput and reducing or minimizing idle times in production of semiconductor wafers used in the fabrication of integrated circuits and flat panel displays. In particular, the invention relates to a method and apparatus for improving and optimizing the rate of transfer of wafers between successive stations of a production line.

**Background of the Invention**

15 The next milestone in semiconductor wafer processing is the transformation from 200mm wafers to 300mm wafers. While the present invention is applicable to both standard 200mm wafers and the next generation 300mm wafers, the following description relates mostly to the more complex 300mm wafers technology.

Semiconductor wafers are processed in processing lines which generally comprise a number of stations. One such station is depicted in Figure 1 and generally indicated at 10. The station 10 comprises a transfer chamber 11 with a suitable platform (not shown). Several process chambers (four in this example) 12 are mounted at four facets of the transfer chamber 11, which, in this example, has six facets. Two load lock chambers 13 are mounted on two other facets of the transfer chamber and connected to the mini-environment (also called Factory Interface, FI) 15, hereinafter described. A robot schematically indicated at 14 operates to transfer the wafers from the load lock chambers 13 to and between the process chambers 12.

Examples of such a station are the Centura™ or Endura™, available from Applied Materials™ of Santa Clara, CA.

The mini-environment, generally indicated at 15, serves as a clean environment for wafer scheduling and handling. Such a mini-environment may be a SMIF-300 Wafer Management System™ available from Asyst Technologies, Inc. of Fremont, CA. It includes an enclosure 16 and several (four in this example) wafer pod loaders 21, 22, 23 and 24. The enclosure 16 houses a track robot 19 for transferring the wafers from the pods to the load lock chamber 13. A suitable track robot is available from Equipe Technologies of Sunnyvale, CA. The robot 19 is also used to transfer wafer to and from the wafer aligner 18.

The work stations could be differently structured and, for instance, comprise other elements, such as a buffer chamber, pre-clean and cool-down chambers, pre-processing and post-processing chambers, and so on. However, the present invention is independent of the particular structure and operation of the work stations, since it concerns the transfer of the wafers from one work station to the next, especially via the mini-environment.

In the present state of the art, the wafers are conveyed to each work station by means of pods (or cassettes), are transferred from the pods by the robots 19 and 14 to the various positions they have to occupy successively in the work stations, and when the processing stages that take place in that station are completed, the wafers are returned to the pods and the pods are then transferred to the next station, where they and the wafers carried thereby are handled in the same way. This method of transfer tends to reduce throughput because of the various transfer motions that are required. Throughput can also be unfavorably affected by imperfect synchronization between

adjacent stations. Considering two adjacent stations, A and B, station B will not be filled with wafers until station A has completed processing all the wafers of at least one pod and the pod is then transferred to station B. Even if station B operates at exactly the same rate as station A, it may remain idle for the time required to process  
5 the wafers of the whole pod. If station A is delayed for any reason, the idle time may considerably increase. There is no way in the art for controlling the flow of wafers through the processing line in order to eliminate, or at least to minimize, idle times.

Additionally, transferring the pods between stations can increase the number of defects on the wafer. This issue becomes increasingly important as design rules are  
10 reduced, thereby making even minute particle killer defects.

### **Summary of the Invention**

It is a purpose of this invention to improve the transfer of wafers along a processing line and between adjacent work stations so as to eliminate, or at least  
15 minimize, said idle times.

It is another purpose of this invention to provide control means for maintaining the flow of wafers through the processing line at an optimal rate at all times.

It is a further purpose of this invention to provide method and apparatus means  
20 for achieving the aforesaid purposes.

It is a still further purpose of this invention to provide means for the early detection of any malfunction in the processing line.

Other purposes and advantages of the invention will appear as the description proceeds.

The present invention provides a method of transfer of wafers between two adjacent work stations, hereinafter called the “preceding” or A stations and the “following” or B, station, respectively, which method comprises individually transferring all or some of the wafers, after they have been processed in the preceding work stations, to a buffer station and therefrom to the following work station, instead  
5 of returning them to a pod at the preceding work station and transferring the pod to the following work station, as in the prior art. Thus, the present invention provides for “per-wafer” processing line, rather than the conventional “per-pod” processing line. Preferably, the transfer of wafers to and from the buffer station is carried on by the  
10 robot of the mini-environment. While the buffer station can be a simple stage having no operable functions, preferably the buffer station includes an inspection or metrology tool.

#### **Brief Description of the Drawings**

15 In the drawings:

Fig. 1 is a schematic plan view of a work station according to the prior art;

Fig. 2 is a schematic plan view of individual wafer transfer between adjacent work station according to an embodiment of the present invention;

20 Fig. 3 is a schematic plan view of a second embodiment of the present invention;

Fig. 4 is a schematic plan view of a third embodiment of the present invention;

Fig. 5 is a schematic plan view of a fourth embodiment of the present invention;

Fig. 6 is a cut-away view of a buffer station suitable for use in the embodiment depicted in Fig. 5.

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### Detailed Description of Preferred Embodiments

Fig. 2 schematically illustrates an embodiment of the invention, comprising two adjacent work stations 30 and 40. These are indicated in this drawing in broken lines. The mini-environments of the two work stations are indicated respectively by  
10 numerals 31 and 41. The lock load chambers are indicated respectively by numerals 32 and 42, the pod loaders by numerals 33-36 and 43-46; and the wafer aligners are indicated by numerals 37' and 47'. As noted above, in the prior art, wafer transfer between the stations 30 and 40 can be performed only by moving pods. Thus, the processing of all the wafers of a particular pod must be completed before the pod can  
15 be transferred to the next station.

According to the present invention, single wafer transfer is made possible, so that a "per wafer" processing can be achieved. Specifically, according to the embodiment of Figure 2, a buffer station 50 is placed between the two mini-environments 31 and 41 of work stations 30 and 40. As will be discussed in the  
20 following disclosure, the buffer station can be implemented as a simple support structure, can be a part of the mini-environments, or can include an inspection and/or metrology tool.

In Figure 2, the buffer station 50 includes an inspection tool 51, such as, for example, disclosed in patent application, Attorney's Docket No. 2417. The inspection

tool 51 is schematically indicated as comprising a mechanical structure 52, which actuates, by means not shown, a rotating turntable 53 upon which is mounted a wafer 54. Said wafer is rotated by turntable 53 and is scanned by scanning means, not shown, which can be of any suitable kind, insofar as this invention is concerned. In particular, the scanning may be carried out by laser beams and the wafer be classified as containing or not containing suspect pixels, depending on the reaction of pixels to the scanning, said reaction being defined by the intensity of the light scattered by each pixel in a number of directions. The inspection tool 51 may comprise one or more optical heads, all described in said co-pending application, Attorney's Docket No. 2417. Moreover, it should be understood that any conventional X-Y stage can be used instead of the turntable 53, so as to effect an X-Y scanning of the wafer, rather than an r-theta scanning. Alternatively, the wafer may be held stationary and the optical head can be scanned over the wafer.

The patent application Attorney Docket No. 2417, the contents of which are herein entirely recalled by referenced, discloses a wafer inspection control apparatus which can be used to detect suspected defects in wafers, and among them, defects which indicate a malfunction of the processing line, possibly so severe as to require taking a chamber off the production line for purposes of repair or maintenance. According to the invention disclosed in said application, the wafers are individually inspected/controlled by loading them on a device that rotates them about their centers, scanning their surfaces with any appropriate means, e.g., by means of a laser beam, and evaluating the response of each pixel of the wafer surface to the scanning, whereby wafers are classified as approved or suspect wafers, according to said response. Preferably, according to this embodiment of the invention, a wafer



inspection or control apparatus, as described in the said patent application is located between the work stations 30 and 40, and occupies and constitutes the buffer waiting station 50. In this embodiment, therefore, the transfer of the individual wafers between the work stations is carried out by transferring each wafer, which has  
5 undergone all the processing stages at work station 30 and has been returned to the mini-environment 31, to the wafer control apparatus 51, and effecting therein the inspection or control of the wafer. Then, the approved wafers are transferred to the following work station 40. Suspect wafers can be taken off line to another apparatus, not shown, which effects further control of the suspect wafers or carries out other  
10 operations. Transfers of the individual wafers are preferably carried out by robots 36 and 43, or may be assisted by an optional dedicated robot 55.

The amount of wafers that are so individually transferred is controlled by the FAB controller, so as to maximize throughput, or, in other words, to eliminate or minimize idle time. The programmed control of the individual wafers transfer will be  
15 understood from the following considerations. Ideally, if two successive stations A and B worked at same production rate, and no wafers from station A were found suspect by an inspection device interposed between the two stations, the transfer of wafers from station A to station B could occur entirely through the inspection device and by the handling of individual wafers, and the wafer pods would be used only for  
20 loading station A and unloading station B, or, if more than two successive stations are so connected, only for loading the first station and unloading the last station.

However, this ideal situation will not occur often. First of all, each process stage has its own duration and this alone would prevent complete synchronization between different work stations. Further, the production rate in a work station is

determined not only by the time required for the various process stages, but also by the motions which the robots must make in order to transfer the wafers within the station. By decreasing the number of wafers that are returned to the pods in station A, the overall throughput of station A is increase; and if station B, at a particular time, 5 has a higher rate of work, and would be idle if it had to wait for station A to fill a pod and for the pod to be transferred, it can be kept in operation by transferring wafers individually, according to the invention.

Transferring the wafers individually between adjoining stations, as provided by this embodiment, has the further advantage that they are inspected/controlled in 10 their transfer between stations. Not all of the wafers are controlled, or need to be controlled. The control is generally statistical in nature. A statistical control, however, is sufficient to reveal serious malfunctions in a work station, in this case, station A. If a serious malfunction were not detected, defective wafers would continue to be fed through the line and would be detected only after processing had 15 been completed, a considerable waste of time and material. In any case, it is a waste of production time and operations to let wafers go down the production line to the end of it, and only then detect defects that may have occurred in an early work station.

Many phenomena may occur in semiconductor wafers production lines that cause deviation from a flawless operation and interfere with the regular flow of the 20 wafers. Providing two manners of wafer transfer - by pods and individually - affords an elasticity of operation that results in production efficiency. A general control of wafer transfer should receive as pertinent data inputs: a) the programmed processing times of each work station; b) the times required for the transfers within each station; c) the time required for pod unloading and loading; d) the statistic percentage of

rejects (suspect wafers) of each station; e) detected and/or foreseen work station malfunctions. Based on said data, a program can be formulated to determine the ratio of processed wafers that are individually transferred and the ratio of individually transferred wafers that are controlled and to react to any change in the input data to  
5 vary said ratios, so as to optimize the flow of wafers through the processing line.

In operation, when processing of a wafer is completed in station 30, track robot 36 transfers the wafer to the buffer station 50. Depending on the respective throughput of the stations 30 and 40 and the inspection tool 51, all wafers may be inspected, or a sampling plan may be implemented. If the wafer is to be inspected, the  
10 inspection tool 51 inspects the wafer and, upon completion, indicated to the controller of track robot 43 that the wafer is ready to be moved to station 40. When station 40 is ready to accept the wafer, track robot 43 retrieves the wafer from buffer station 50 and inserts it into one of the load lock chambers 42.

Depending on the throughput of the workstations 30 and 40, the inspection  
15 tool can also be used by both stations synchronously. For example, when work station 30 completes processing of a wafer, it sends it via the track robot 36 to the inspection station 51. If the wafer has no defects, it is then delivered to work station 40 by track robot 43. When work station 40 completes processing of the wafer, it then returns the wafer to the inspection station 51 for a second inspection. However, such  
20 processing requires the fab controller to synchronize the operations of the track robots 36 and 43 to use the inspection station 51 one at a time.

Figure 2 also depicts (in broken lines) an optional dedicated robot 55. This robot can be used to transfer wafers from the mini-environment 31 of station 30 to the mini-environment 41 of station 40, or to take out suspected faulty wafers from the

inspection tool 51. Thus, for instance, in cases where inspection of the wafer reveals a potentially defective situation, and the wafer must be transferred to further inspection apparatus (not shown), robot 55 may remove it from the fabrication line from further processing.

5           According to another embodiment of the invention, depicted in figure 3, buffer station 50 has no operative function. Rather, it merely serves as a waiting station for the wafers. Thus, the buffer station 50 may include a table 56 supporting a vacuum or electrostatic chuck 58 for supporting the wafer. In operation, track robot 36 places the wafer on the chuck 50, and track robot 43 retrieves the wafer from the  
10   chuck 58.

          According to a further embodiment, depicted in Figure 4, the buffer station is eliminated. Instead, the robots 36 and 43 perform a "handoff" operation between each other whenever a wafer needs to be transferred. This embodiment, however, may require a fine tuning of the throughput of stations 30 and 40, and a delicate tuning of  
15   the robots 36 and 43. A more preferred embodiment is depicted in Figure 5, wherein a buffer station 50' is inserted partially in station 30 and partially in station 40, and includes a chuck 58' for holding the wafer in transfer. Moreover, as shown in figure 6, buffer station 50' may include several chucks 58' for holding several wafers. This can be easily accomplished since not much of the vertical space of the mini-  
20   environment is occupied.

          Specifically, Figure 6 depicts parts of the two mini-environments 31 and 41 with the walls removed. Track robot 36 is depicted with its arm vertically retrieved, while track robot 43 is depicted with its arm partially vertically elevated. Such a vertical movement is standard with track robots, such as that available from Equipe

Technologies. In the particular example of Figure 6, three pin chucks 58' are depicted arranged one above the other. A wafer 59 is depicted resting on the middle chuck. Using this arrangement, track robot 36 can place wafers on the chucks on its own pace, while track robot 43 can retrieve the wafer on its own pace.

5           It should be appreciated that the arrangement of Figure 6 can be used in conjunction with the inspection station 51 of Figure 2. Such an arrangement can be advantageously used when both work stations 30 and 40 use the inspection station 51 for inspecting the wafers after processing as described above. Thus, the pin chucks 58 can be used to synchronize the inspection of wafers from two stations. Alternatively,  
10   one or more wafer pods, connected to any of pod loaders 33-36 and 43-46, can be used as a "buffer" pod for pods in a queue for the inspection station 51.

          While some embodiments of the invention have been described by way of illustration, it will be apparent that the invention can be carried out with many modifications, variations and adaptations, without departing from its spirit or  
15   exceeding the scope of the claims.

**CLAIMS**

1. A method for transferring wafers between two adjacent work stations in a processing line for the manufacture of semiconductor wafers, comprising:  
individually transferring wafers, after they have been processed in a first  
5 work station, to a waiting station, and therefrom to a second work station.
2. The method according to claim 1, wherein the transfer of wafers between two adjacent work stations comprises individually transferring wafers from a first work station to a wafer control apparatus, effecting therein the  
10 control of the wafers, and transferring wafers approved by the control apparatus to a second work station.
3. The method according to claim 2, further comprising transferring the wafers that have not been approved by the control apparatus, to other  
15 apparatus, which effects a further control thereof.
4. A buffer station for transferring individual wafers from a first processing station to a second processing station, comprising:  
a table; and,  
20 a chuck positioned on said table and configured to support wafers.
5. The buffer station of claim 4, further comprising an inspection tool.

6. A semiconductor processing module, comprising: a first processing station having plurality of chambers; a first interface connected to said first processing station and designed to receive and support wafer pods; a first track robot situated inside said first interface; a second processing station having plurality of chambers; a second interface connected to said second processing station and designed to receive and support wafer pods; a second track robot situated inside said second interface; a buffer station having a wafer support and configured to receive wafers from said first track robot and store them until retrieval by said second track robot.

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7. The semiconductor processing module of claim 6, wherein said buffer station comprises one of a wafer inspection and metrology tools.

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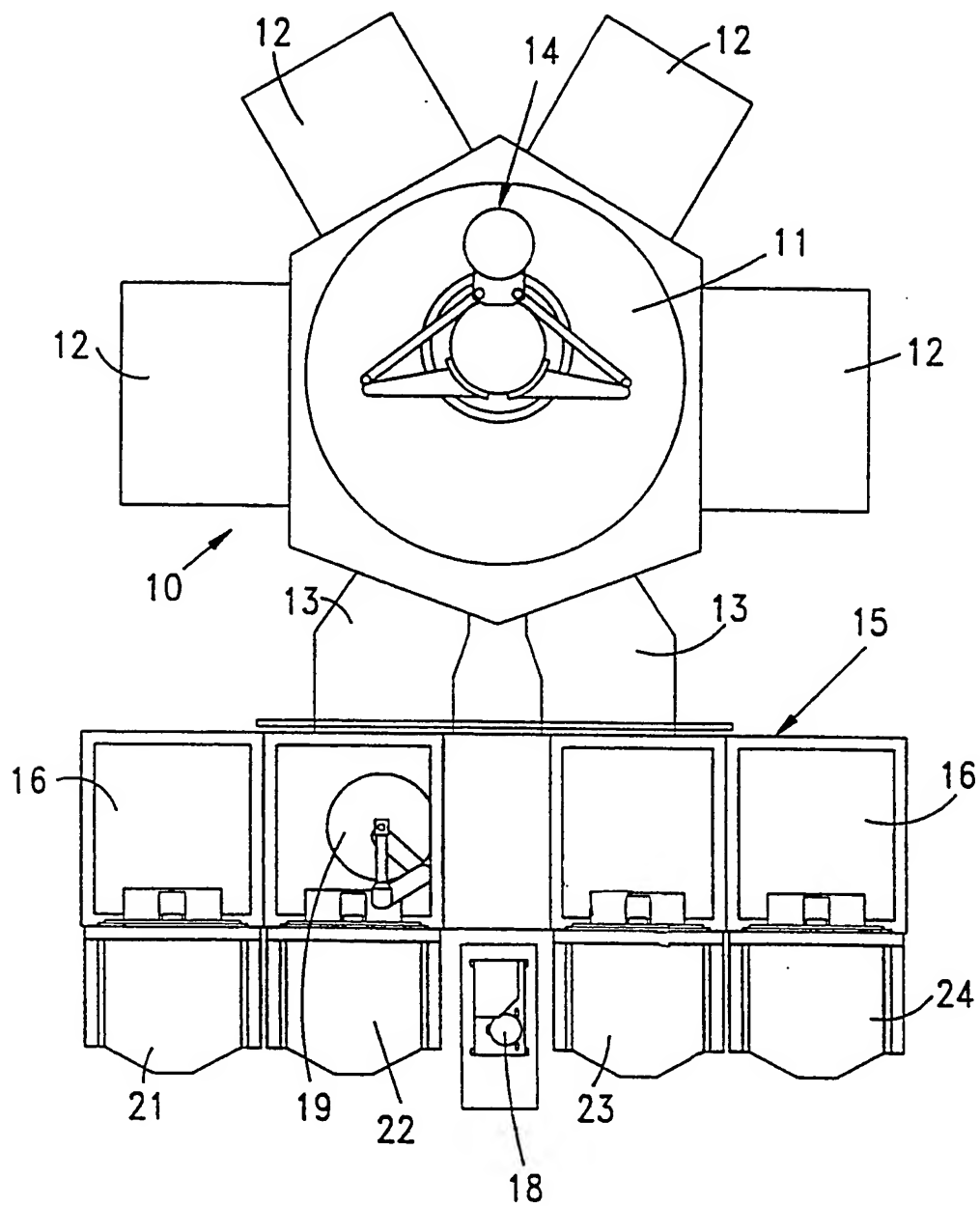


Fig. 1



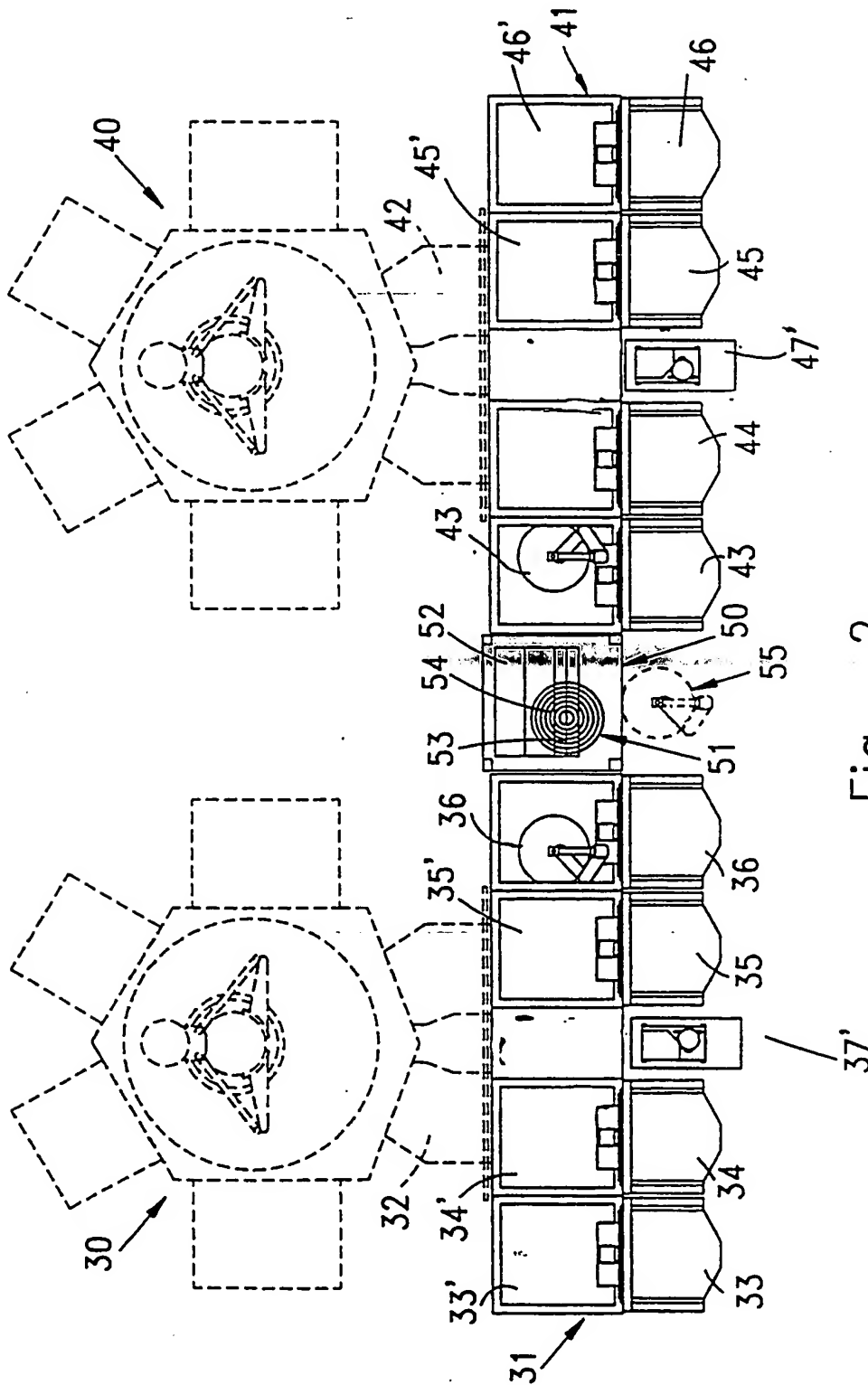


Fig. 2

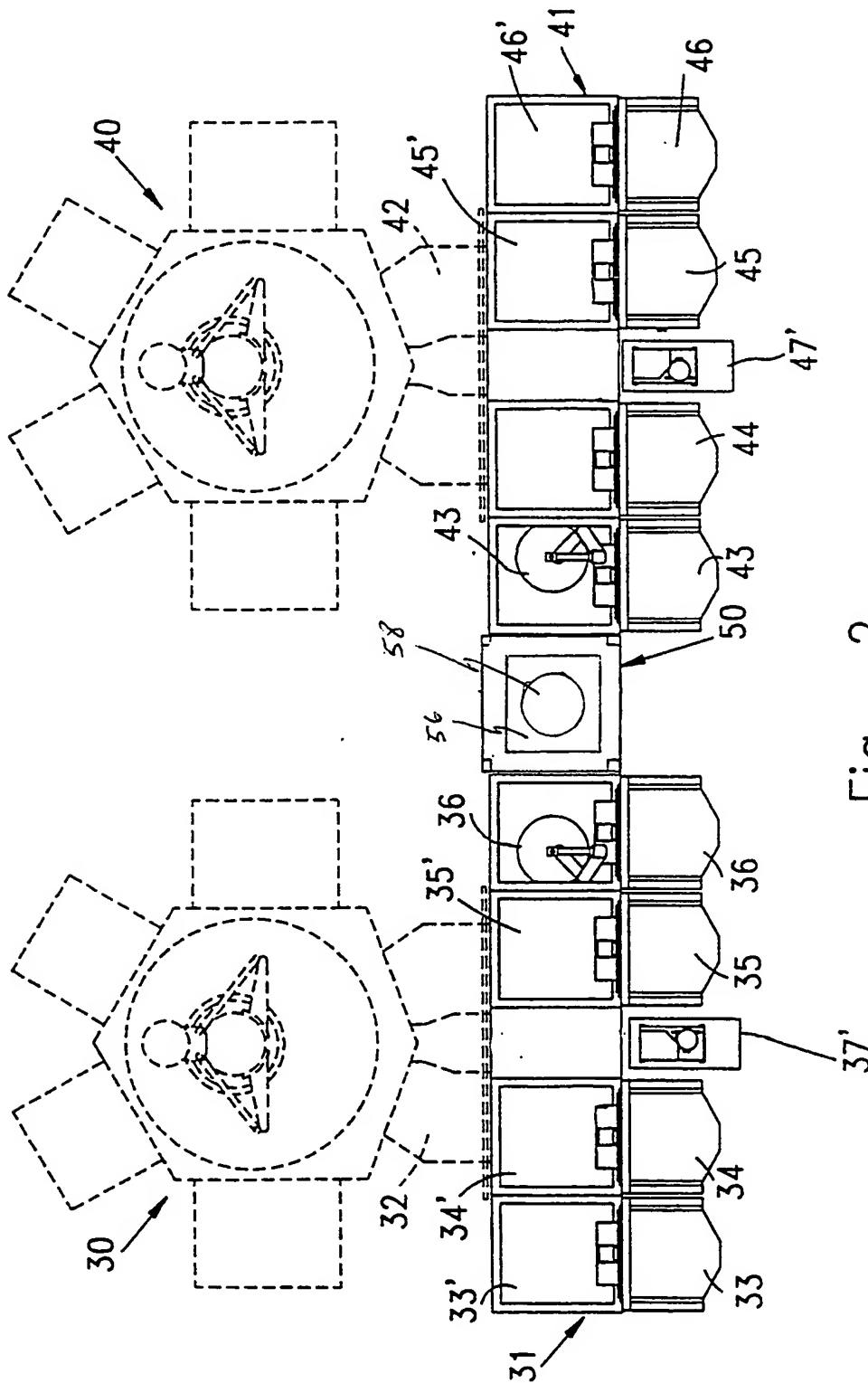


Fig. 3

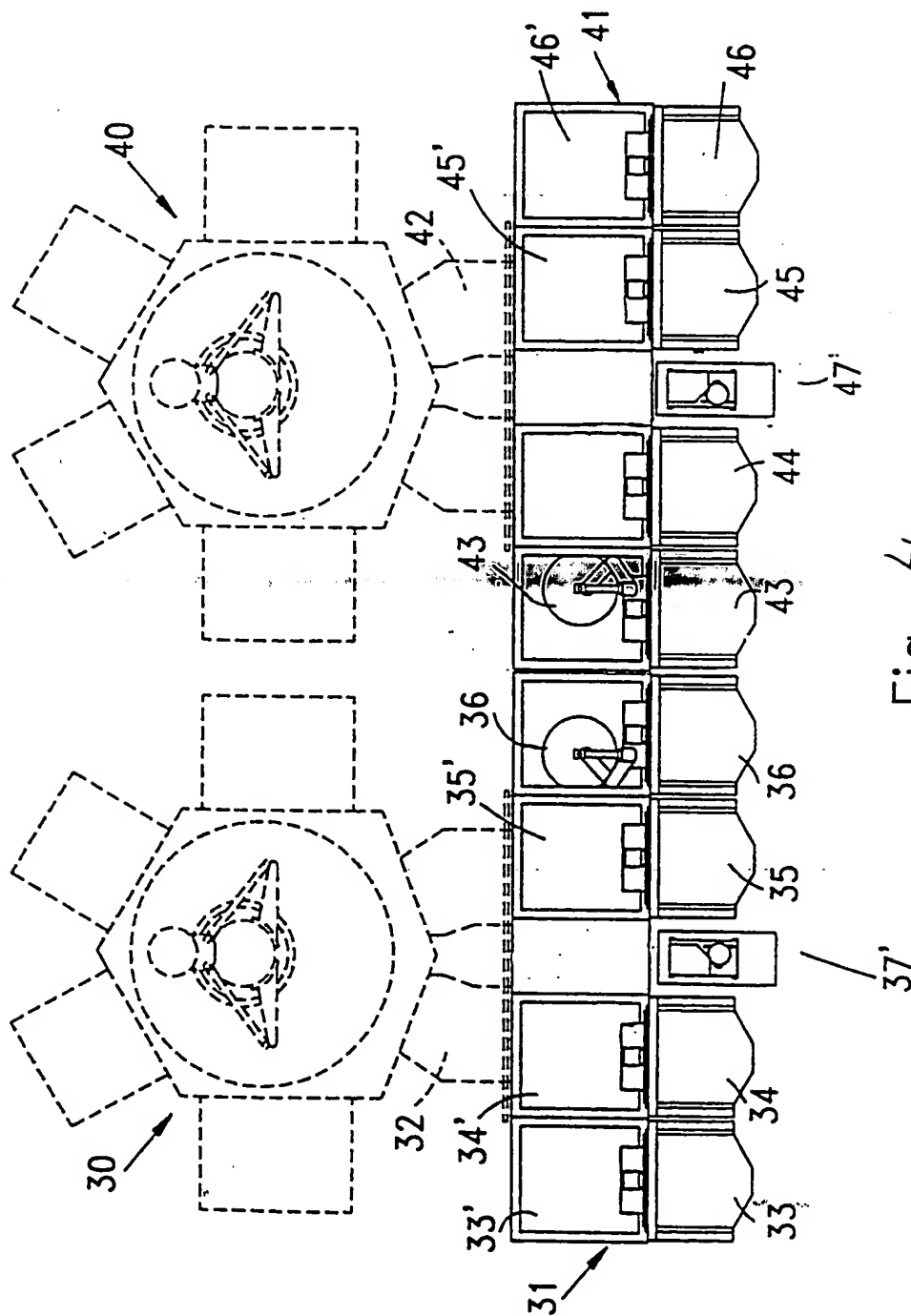


Fig. 4

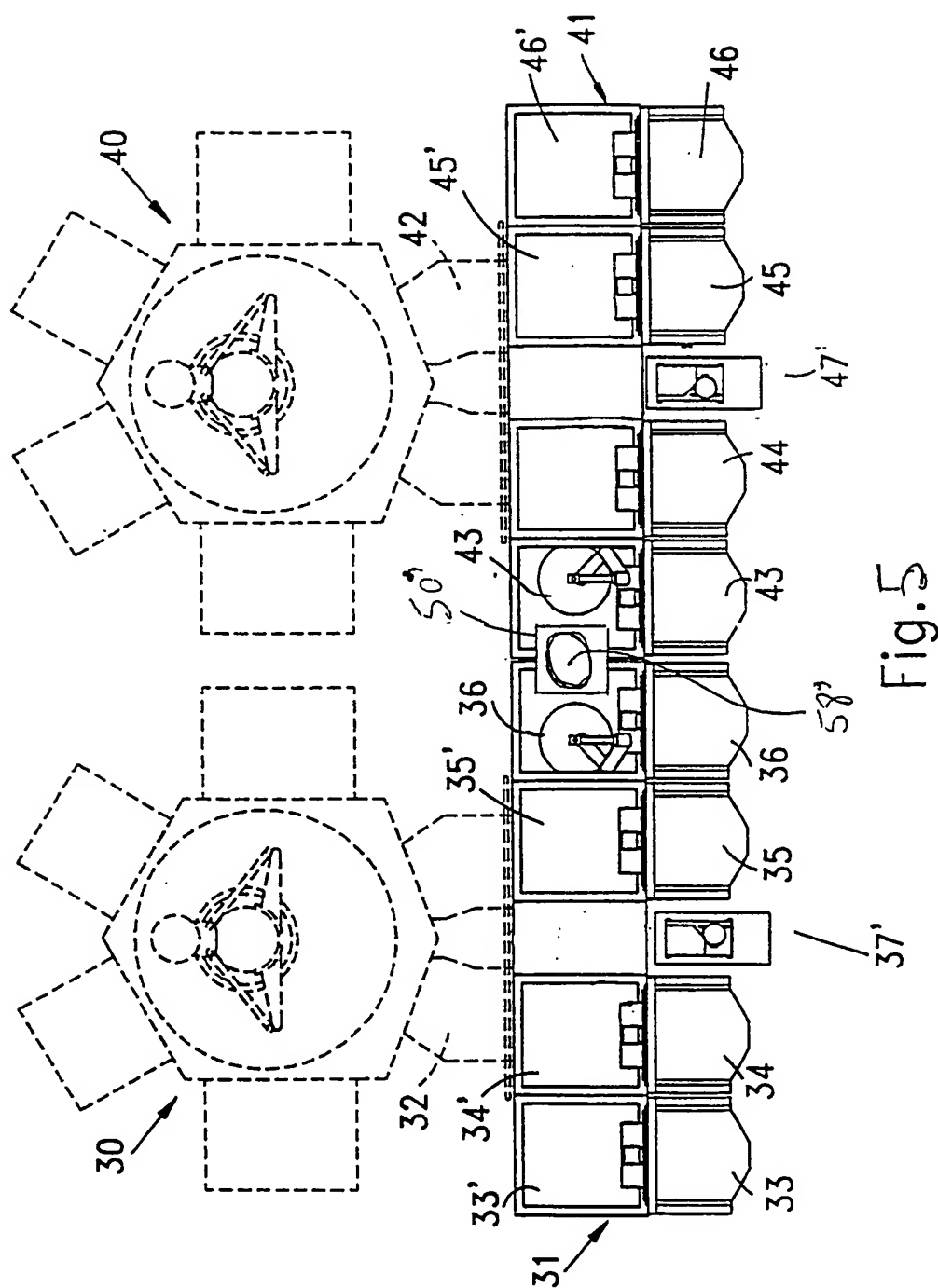


Fig. 5

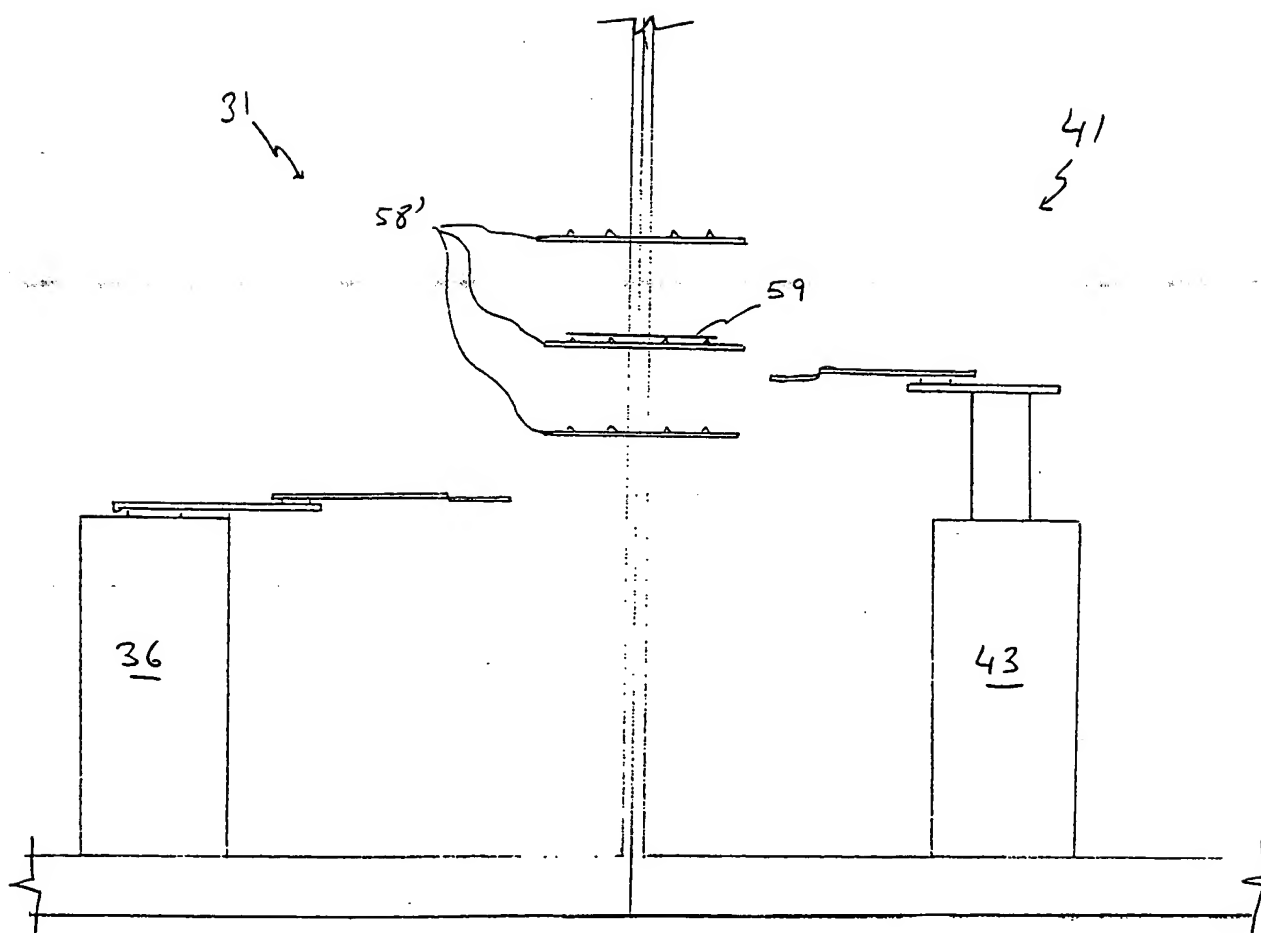


Fig 6

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 99/09602

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 6 H01L21/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	column 10, line 27 - column 11, line 46; claims 1,2; figures 7,10,13 ---	6
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☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

9 September 1999

Date of mailing of the international search report

16/09/1999

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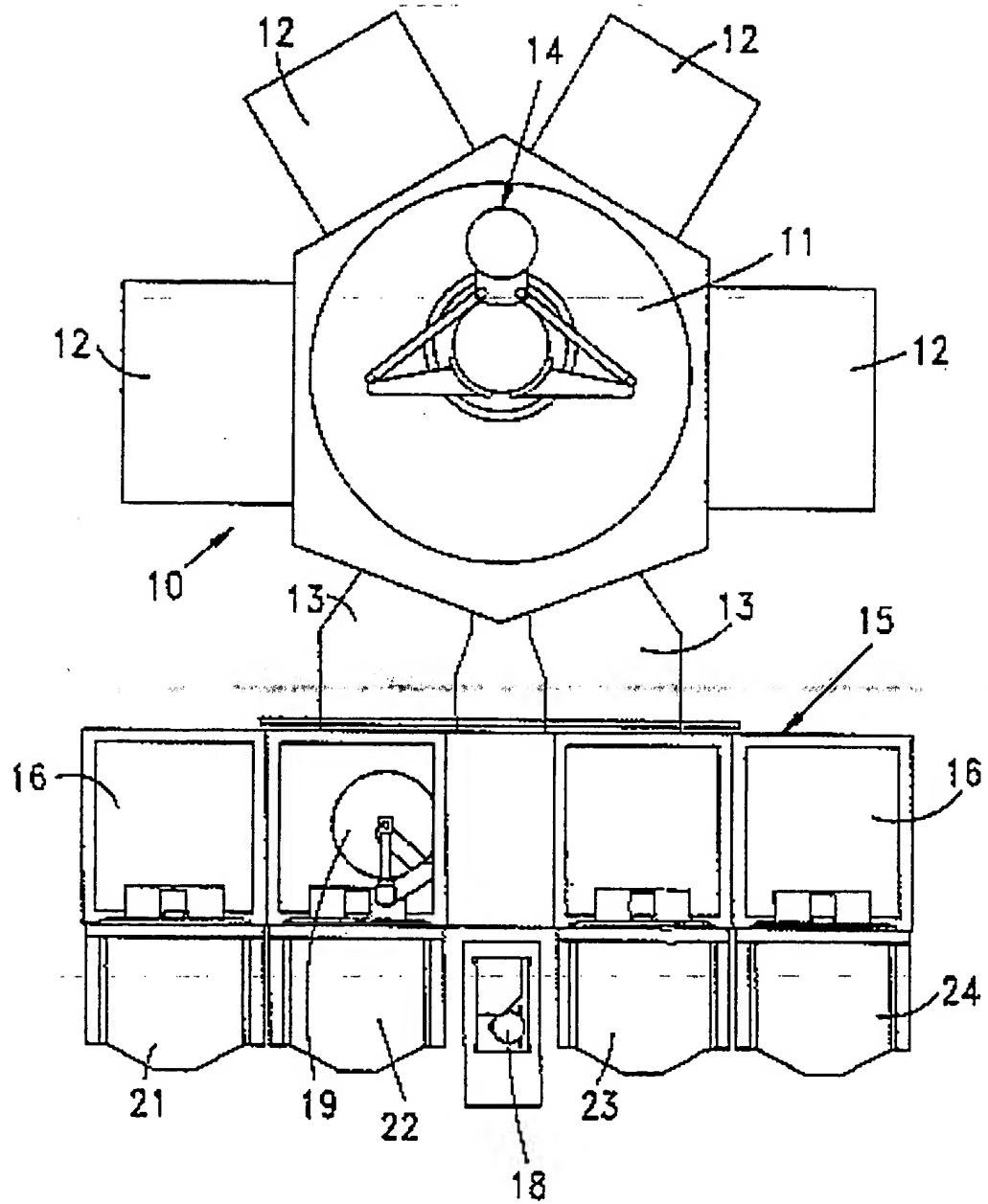


Fig. 1

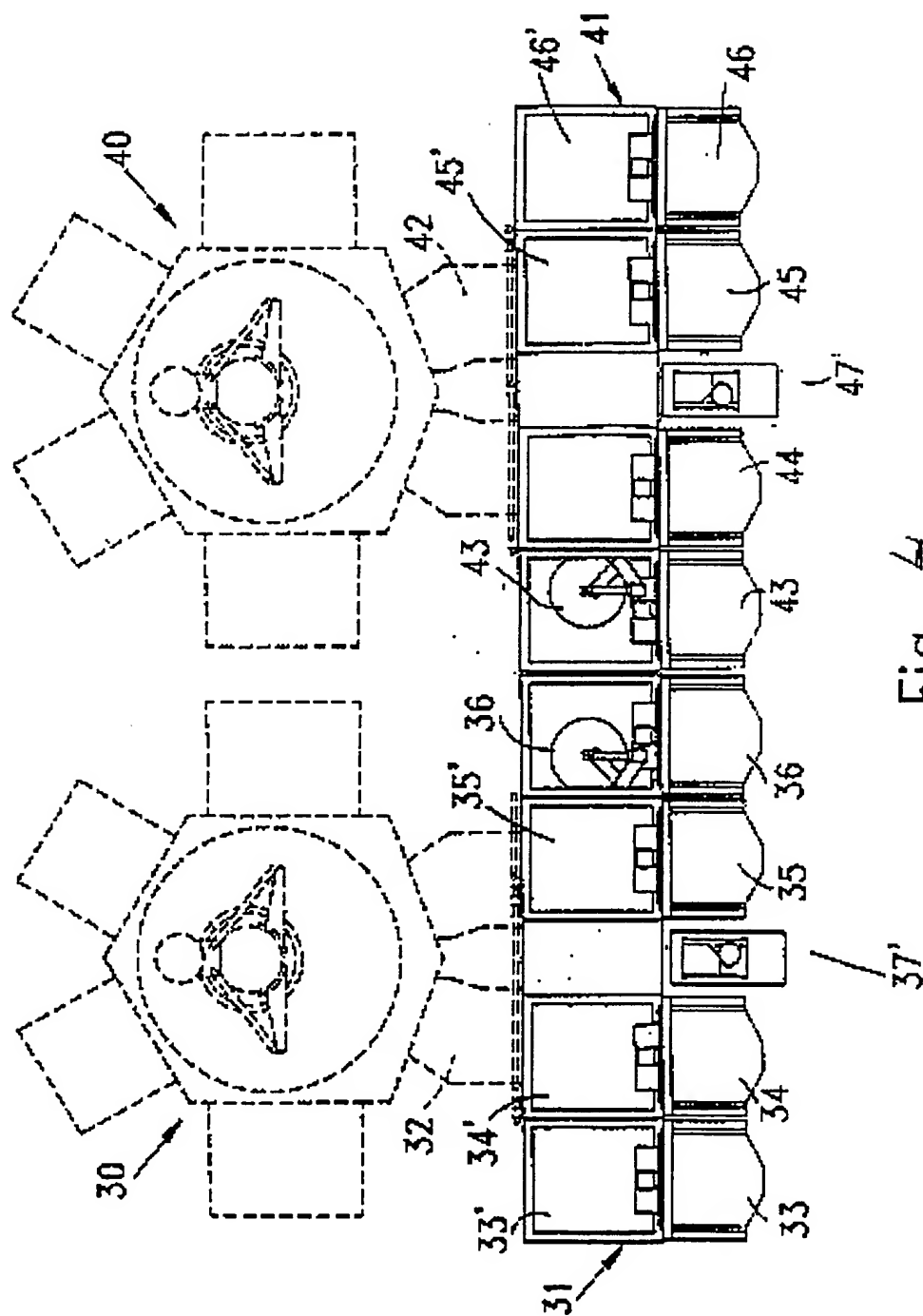


Fig. 4

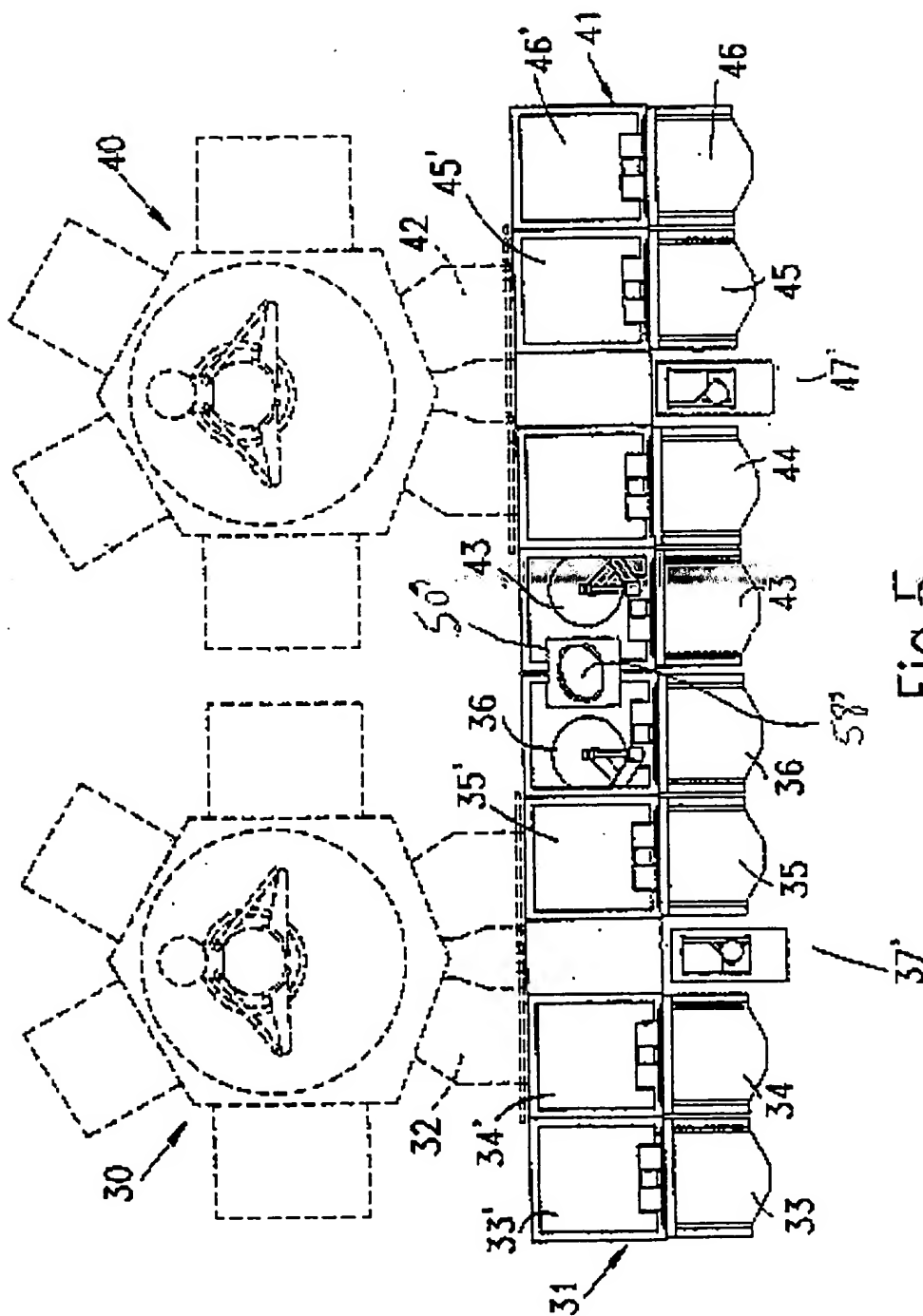


Fig. 5

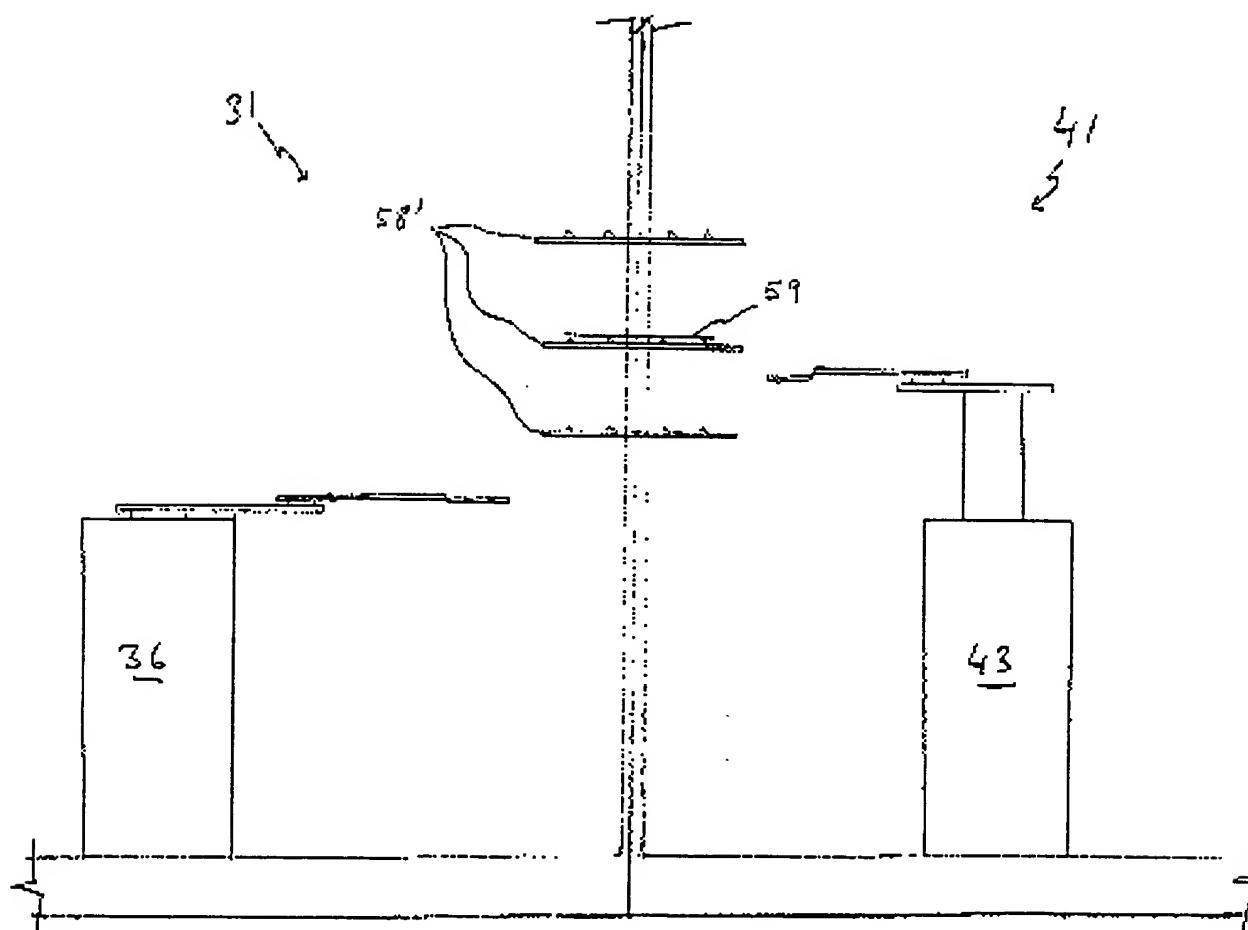


Fig 6